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HEMISPHERE SEARCH DETECTOR

Progress Report No. 7

(Period November 2, 1948, to December 6, 1948)

Under

U.S. Navy Contract No. NObsr-42179

December 6, 1948

Polaroid Corporation

Research Department

Cambridge 39, Massachusetts

(Project RC-5)

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Work has continued on the electronic and mechanical aspects of the 18-element scanner proposed in the report dated August 18 by Grey and Jones. Work has also been continued on the computation of the "Effect of Atmospheric Absorption on the Response of Infrared Detectors."

A meeting was held in Washington November 22 attended by Mr. Dauber of the Navy and Drs. Blout and Jones of the Polaroid Corporation. The minutes of this meeting are attached as enclosure 2.

A meeting was held at the Polaroid Corporation on November 12 to discuss the mechanical aspects of the proposed search detector. The minutes of this meeting are attached as enclosure 3.

Three reports by Dr. Stockman dated December 2, November 22, and December 3 are attached as enclosures 4, 5, and 6.

At the request of Mr. Dauber, Tables III, IV, and V in the writer's report dated September 24, 1948, have been extended to include two additional source temperatures. A report containing the extended tables is attached as enclosure 1.

The subjects discussed in enclosure 2 include the procurement of detectors, the problems of presentation and sun protection, and a list of specific task agreements.

Enclosure 3 contains an estimate of the weight of the various parts of the proposed search detector. It contains also a discussion of the means by which the light falling on the photoconductive cell is to be chopped. A specific mechanical design is proposed. The minutes include also a discussion of the details of the chopping process and a discussion of the signal-to-noise ratios to be obtained with several modifications proposed by Mr. Grey and Dr. Matz.

Enclosure 4 contains a specific proposal for the presentation to be used with the hemispheric search detector, including the use of magnetic storage. The proposed presentation scheme involves 12 oscilloscope screens (six for each of the two separate detecting systems). Mr. Dauber has suggested modifying this proposal so that the total number is reduced from 12 to four.

Enclosure 5 contains a discussion of the mechanical design of the hemispheric search detector.

Enclosure 6 contains a discussion of the anti-zigzag circuit to be used to compensate for the fact that the detecting elements will necessarily be staggered in position.

Part II of the series of three papers on the "Effect of Atmospheric Absorption on the Response of Infrared Detectors" has been completed and duplicated copies have been prepared. Circulation of this report, dated November 24, 1948, will be delayed, however, because the writer has not yet received 20 copies of a Weather Bureau report which is to be circulated as an attachment to Part II.

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Report prepared by R. Clark Jones
R. Clark Jones

Approved by Elkan R. Blout
Elkan R. Blout
Associate Director of Research

Enclosure 1

Effect of Atmospheric Absorption on the Response of Infrared Detectors

Supplement to Part I

R. Clark Jones

December 2, 1948

This is a supplement to the writer's report dated September 24, 1948, which report was the first of a series of three reports on the subject indicated by the title.

The results contained in Tables III, IV, and V of the September 24 report have been extended to include two additional source temperatures. The Tables III, IV, and V in the September 24 report contained results for the source temperatures 350°, 400°, 500°, and 600° K; this supplement contains the same tables with two additional source temperatures: 800° and 1000° K.

The rather extensive calculations leading to the entries in Table III were again carried out by Mrs. Samuel Stone. Tables IV and V were calculated by the writer.

The new entries in the tables have not been smoothed with respect to the former entries. Each of the individual entries in these tables is probably within ± 10 percent of the correct value. These errors are all due to the fact that the calculations were carried out graphically.

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Table III

Values of J_{eff} in ergs/(cm^2-sec)

	Equivalent Thickness of Water Vapor = τ					
	0.0 cm	0.1 cm	1.0 cm	2.5 cm	10.0 cm	50.0 cm
Thermocouple						
1000°	56,000,000	34,000,000	34,000,000	26,000,000	17,000,000	9,200,000
800°	22,000,000	16,000,000	12,000,000	9,800,000	5,600,000	3,800,000
600°	6,600,000	4,400,000	3,600,000	2,300,000	1,100,000	540,000
500°	2,900,000	2,000,000	1,600,000	980,000	360,000	160,000
400°	910,000	550,000	460,000	280,000	66,000	22,000
350°	330,000	230,000	190,000	110,000	18,000	5,000
PbS, 290° K						
1000°	14,000,000	12,000,000	9,600,000	6,800,000	5,800,000	3,400,000
800°	2,700,000	2,500,000	1,800,000	1,200,000	1,000,000	630,000
600°	230,000	220,000	150,000	96,000	73,000	37,000
500°	36,000	32,000	22,000	12,000	9,200	4,500
400°	2,400	2,100	1,300	560	430	190
350°	300	260	140	53	46	18
PbS, 195° K						
1000°	19,000,000	17,000,000	13,000,000	8,200,000	6,500,000	3,600,000
800°	4,300,000	4,000,000	2,900,000	1,600,000	1,300,000	750,000
600°	420,000	370,000	230,000	100,000	81,000	37,000
500°	74,000	66,000	39,000	14,000	10,000	5,000
400°	5,800	5,200	3,500	850	540	260
350°	930	840	560	130	76	28
PbS, 90° K						
1000°	26,000,000	24,000,000	19,000,000	13,000,000	10,000,000	6,400,000
800°	6,600,000	6,300,000	5,100,000	3,400,000	2,600,000	1,800,000
600°	730,000	690,000	530,000	320,000	190,000	120,000
500°	160,000	140,000	120,000	72,000	49,000	25,000
400°	16,000	15,000	14,000	8,800	6,100	3,700
350°	3,100	3,100	2,700	2,000	1,500	720
PbSe, 195° K						
1000°	29,000,000	27,000,000	22,000,000	16,000,000	13,000,000	7,800,000
800°	8,300,000	8,000,000	6,700,000	5,000,000	4,000,000	2,300,000
600°	1,200,000	1,200,000	1,000,000	790,000	630,000	390,000
500°	300,000	300,000	270,000	210,000	180,000	100,000
400°	40,000	39,000	37,000	31,000	27,000	15,000
350°	8,700	8,600	8,200	7,400	6,400	3,800
PbSe, 90° K						
1000°	36,000,000	34,000,000	28,000,000	21,000,000	17,000,000	9,200,000
800°	11,000,000	11,000,000	9,000,000	6,800,000	5,300,000	3,000,000
600°	2,000,000	2,000,000	1,700,000	1,400,000	1,100,000	540,000
500°	600,000	570,000	490,000	410,000	320,000	160,000
400°	100,000	100,000	79,000	72,000	51,000	22,000
350°	26,000	22,000	21,000	19,000	12,000	5,000

Table IV

Values of the Attenuation Factor = $J_{eff}(\tau)/J_{eff}(\tau = 0)$

	0.0 cm	0.1 cm	1.0 cm	2.5 cm	10.0 cm	50.0 cm	
1000°	1.0	0.60	0.60	0.46	0.30	0.17	Thermocouple
800°	1.0	0.73	0.55	0.45	0.25	0.17	
600°	1.0	0.70	0.54	0.35	0.17	0.08	
500°	1.0	0.69	0.55	0.34	0.12	0.055	
400°	1.0	0.60	0.51	0.31	0.07	0.024	
350°	1.0	0.70	0.57	0.33	0.055	0.015	
1000°	1.0	0.86	0.68	0.48	0.41	0.24	PbS, 290° K
800°	1.0	0.93	0.67	0.44	0.37	0.23	
600°	1.0	0.96	0.65	0.42	0.32	0.16	
500°	1.0	0.89	0.61	0.33	0.25	0.12	
400°	1.0	0.87	0.54	0.23	0.18	0.08	
350°	1.0	0.87	0.47	0.18	0.15	0.06	
1000°	1.0	0.90	0.68	0.43	0.36	0.19	PbS, 195° K
800°	1.0	0.93	0.67	0.37	0.30	0.17	
600°	1.0	0.88	0.55	0.24	0.19	0.09	
500°	1.0	0.89	0.53	0.19	0.14	0.07	
400°	1.0	0.90	0.60	0.15	0.09	0.045	
350°	1.0	0.90	0.60	0.14	0.08	0.030	
1000°	1.0	0.92	0.73	0.50	0.38	0.25	PbS, 90° K
800°	1.0	0.95	0.77	0.52	0.39	0.27	
600°	1.0	0.95	0.73	0.44	0.26	0.16	
500°	1.0	0.88	0.75	0.45	0.31	0.16	
400°	1.0	0.94	0.88	0.55	0.38	0.23	
350°	1.0	1.0	0.87	0.64	0.48	0.23	
1000°	1.0	0.93	0.76	0.55	0.38	0.27	PbSe, 195° K
800°	1.0	0.96	0.80	0.60	0.48	0.32	
600°	1.0	1.0	0.83	0.66	0.52	0.32	
500°	1.0	1.0	0.90	0.70	0.60	0.33	
400°	1.0	1.0	0.92	0.78	0.68	0.38	
350°	1.0	1.0	0.94	0.85	0.74	0.44	
1000°	1.0	0.94	0.78	0.58	0.47	0.26	PbSe, 90° K
800°	1.0	1.0	0.82	0.62	0.48	0.27	
600°	1.0	1.0	0.85	0.70	0.55	0.27	
500°	1.0	0.95	0.82	0.68	0.53	0.27	
400°	1.0	0.90	0.79	0.72	0.51	0.22	
350°	1.0	0.85	0.81	0.73	0.46	0.19	

Table V

Fraction of the Total Incident Energy Which the Detector Utilizes
$\cong J_{eff}(\text{Thermocouple})/J_{eff}\ (\text{Photocell})$

	0.0 cm	0.1 cm	1.0 cm	2.5 cm	10.0 cm	50.0 cm	
1000°	1.0	1.0	1.0	1.0	1.0	1.0	**Thermocouple**
800°	1.0	1.0	1.0	1.0	1.0	1.0	
600°	1.0	1.0	1.0	1.0	1.0	1.0	
500°	1.0	1.0	1.0	1.0	1.0	1.0	
400°	1.0	1.0	1.0	1.0	1.0	1.0	
350°	1.0	1.0	1.0	1.0	1.0	1.0	
1000°	0.25	0.35	0.28	0.26	0.34	0.37	**PbS, 290° K**
800°	0.12	0.15	0.15	0.12	0.18	0.17	
600°	0.035	0.050	0.041	0.041	0.066	0.068	
500°	0.012	0.016	0.013	0.012	0.026	0.028	
400°	0.0026	0.0038	0.0028	0.0020	0.0065	0.0086	
350°	0.0009	0.0011	0.00074	0.00048	0.0025	0.0036	
1000°	0.34	0.50	0.38	0.32	0.38	0.39	**PbS, 195° K**
800°	0.20	0.25	0.24	0.16	0.23	0.20	
600°	0.064	0.084	0.063	0.044	0.073	0.068	
500°	0.025	0.033	0.025	0.014	0.028	0.031	
400°	0.0064	0.0095	0.0076	0.0030	0.0081	0.012	
350°	0.0028	0.0036	0.0030	0.0012	0.0042	0.0056	
1000°	0.46	0.71	0.56	0.50	0.59	0.70	**PbS, 90° K**
800°	0.30	0.39	0.42	0.35	0.46	0.47	
600°	0.11	0.16	0.064	0.14	0.17	0.22	
500°	0.055	0.070	0.024	0.073	0.14	0.16	
400°	0.018	0.027	0.0076	0.031	0.092	0.15	
350°	0.009	0.013	0.0030	0.018	0.083	0.14	
1000°	0.52	0.79	0.65	0.62	0.76	0.85	**PbSe, 195° K**
800°	0.38	0.50	0.56	0.51	0.71	0.60	
600°	0.18	0.27	0.15	0.34	0.57	0.72	
500°	0.10	0.15	0.075	0.21	0.50	0.63	
400°	0.044	0.070	0.030	0.11	0.41	0.68	
350°	0.026	0.037	0.014	0.067	0.36	0.76	
1000°	0.64	1.00	0.82	0.81	1.00	1.00	**PbSe, 90° K**
800°	0.50	0.69	0.75	0.69	0.95	0.79	
600°	0.30	0.45	0.47	0.61	1.0	1.0	
500°	0.20	0.29	0.31	0.42	0.89	1.0	
400°	0.11	0.18	0.17	0.25	0.77	1.0	
350°	0.08	0.095	0.11	0.17	0.67	1.0	

Enclosure 2

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Minutes of a Meeting in Washington on November 22, 1948

Contract NObsr-42179

R. Clark Jones

November 23, 1948

A meeting was held in Mr. Dauber's office in the Navy Department Building on Constitution Avenue in Washington, D.C. on November 22. The meeting lasted most of the day. Present were Harry Dauber, Bureau of Ships, and Elkan R. Blout and R. Clark Jones, Polaroid Corporation

Scope of Contract

The primary purpose of the meeting was to discuss the possible increased scope of this contract. The discussion included the nature of the extension, a discussion of approximate costs, and also a number of technical details.

As suggested by Mr. Dauber, the scope of the contract would be changed "to include development of an experimental model which will serve to test under tactical conditions the conclusions reached as the result of the system study. This model shall contain the basic elements necessary to demonstrate the principle of hemispheric detection and shall be designed to permit expansion into a model satisfying military requirements."

The technical requirements involved in the construction of the experimental model are:

1. A detector should be land-based or mounted on an existing stable platform, the optical system, the individual channel amplifiers, and the switching tube to be in one unit, the remainder of the equipment in another.

2. The system should be dual throughout. The optical, detecting, and electronic systems will be duplicated. One channel will employ heat detectors and the other photoconductive cells.

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3. In order to avoid complexity in the experimental model, only four channels of the total of 18 will actually be constructed in each of the two systems. These four channels shall cover a continuous range of elevation angles. The range in elevation angle will be 20°. The mean elevation angle of the four detectors will be selected manually by means of a hand crank located on the optical receiver.

4. The detector will scan 360° about a vertical axis.

5. The presentation is to be on cathode ray oscilloscope screens. The presentation will either be by conventional means or by artificial persistence provided by a magnetic storage device to be developed by the Armour Research Corporation.

6. The equipment must withstand Navy tests with regard to shock, vibration, and humidity.

The discussion of the amount of money to be involved in the contract was based on the estimated completion time of 12 months, starting February 1, 1949.

The following amplification refers to the statement that the model "shall be designed to permit expansion into a model satisfying military requirements." This statement does not mean that the same physical structures should be capable of such expansion, but merely that the principles of operation should be such as to permit said expansion. Mr. Dauber suggested that the reflecting mirrors should be made of a size capable of taking the entire 18 elements. The box housing the electronics need not be large enough to contain 18 channels. It will be all right to employ a switching tube with a smaller number of electrodes than 18. It was left to our discretion to decide whether there should be four or 18 presentation channels. It was suggested that the entire optical system should be moved in order to change the mean elevation angle of the four detectors.

Procurement of Detectors

The Navy is willing to supply Harris thermocouples for this contract. This does not mean, however, that we may not procure Hornig and O'Keefe type thermocouples, manufactured by Farrand, if we prefer.

With regard to the photoconductive cells, the Navy will supply Cashman cells.

Cooling of the Photoconductive Cells

The real interest on the part of the Navy in the hemispheric search detector is for the eventual application to submarines. In this application the cooling problem is very difficult. Even if a device such as the Hilsch tube is used, the returning hot air must be brought down the radar mast, and this would mean added weight for thermal insulation. The weight in the mast must be kept down in order to keep the speed at which the mast resonates high. Serious attention should nevertheless be given to an effort to consider a cooling method which is feasible for use on a submarine.

Switching Tubes

The Bureau of Ships will buy directly the switching tubes from the National Union Company. This fact, however, does in no way prevent us from using ordinary electron tubes as switching tubes if we prefer.

Magnetic Storage

Mr. Dauber suggested that we wait until after Christmas to make further inquiry about the details of the magnetic storage device. At the present time the Armour Research Corporation is studying the application of magnetic storage equipment for AN/BAR-2 equipment.

Sun Protection

Because the direct image of the sun falling on any of the detecting elements would burn them out, it is necessary to employ some device to protect the elements from the direct image of the sun. Mr. Dauber approved the use of a shutter which closes the entrance window and keeps it closed for a determinate number of seconds whenever the level in any of the channels rises above a critical level, to be set at approximately 120 db above noise level. A small silver chloride lens will be placed in the entrance pupil to provide a large and relatively low-brightness image of the sun upon which the window may close.

Presentation

Mr. Dauber will consider a modification of a suggestion made by Dr. Stockman. The modified proposal is as follows:

Each of the 18 channels will be represented on a cathode ray screen by a circle concentric with the circles of the other channels. The radius of each circle will be proportional to the angle in the sky between the zenith and the sensitive direction of that channel. There will be two cathode ray oscilloscope presentations. One of the two tubes will be merely a monitor equipped with a long persistence screen. The monitor tube will not make use of magnetic storage. Mr. Dauber suggests that the magnetic storage device should permit the presentation on the screen of any one or any desired combination of the following four scanning periods:

1. The last complete scan.

2. The first complete scan preceding the last complete scan.

3. The second preceding such scan.

4. The third preceding such scan.

If all four scans are placed on the screen simultaneously, it will be possible to see the motion of the target with respect to the detector during the last 60 seconds. The superposing of all four scans is disadvantageous from the point of view of signal-to-noise ratio, however, so that provision must be made for viewing each one of the scanning periods separately.

Low Level Frequency Converter

At the present time the only method by which it appears possible to couple a low impedance thermocouple (approximately 10 ohms) to the grid of a tube at low frequencies (about one cps) by means of equipment which weighs no more than a few ounces is to make use of some means of frequency conversion. Frequency conversion to a carrier frequency of approximately 1000 cps permits the use of a very compact and light-weight transformer. The writer has suggested two possibilities for obtaining this frequency conversion:

1. The use of a balanced second harmonic magnetic amplifier.

2. The use of a balanced modulator employing copper oxide or selenium rectifiers.

Mr. Dauber suggested that Dr. Stockman and the writer meet with representatives of the Naval Research Laboratory in the middle of December to discuss these possibilities, and he further agreed to prepare the way for this meeting by discussing this question in detail with the Naval Research Laboratory prior to the meeting.

Specific Task Agreements

1. Mr. Dauber will set up a meeting in the middle of December to be attended by Naval Research Laboratory representatives and by Dr. Stockman and the writer from Polaroid to discuss low level frequency converter circuits. He further agreed, as mentioned above, to prepare the way by prior discussions with the Naval Research Laboratory on this question. The writer agreed to communicate to Mr. Dauber a list of possible dates in the middle of December.

2. Mr. Dauber will send us information on Armour lead sulfide cells.

3. Mr. Dauber will write us with regard to procurement of lead sulfide cells and thermocouples.

4. Mr. Dauber will send us detailed information on the stabilized platform. This information should be sufficiently complete that by its use we can design equipment to mount on this platform, and also should include information as to the permissible moments of inertia about specified axes.

5. Mr. Dauber will supply us with reports on the method used in radar to derive the optimum screen brightness versus signal level relation.

6. The writer agrees to send to Mr. Dauber one copy of every future report on range of detectors as soon as it is available.

7. Mr. Dauber will obtain information on the methods used in making searchlight reflectors to determine whether the reflectors for the hemispheric search detector may be made by the same method, and to determine whether the reflectors used for the hemispheric search detector can be procured through Army or Navy channels.

8. Mr. Dauber will try to obtain a final ruling on the range of elevation angles handled by the complete hemispheric search detector. His tentative suggestion is 0° to 60°, but this is not final.

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Enclosure 3 CONFIDENTIAL

Minutes of a Meeting to Discuss the Mechanical Aspects of the Hemispheric Search Detector

R. Clark Jones

November 15, 1948

The meeting took place in the fifth floor conference room of the Polaroid Corporation on Friday, November 12, from 10:00 a.m. to 12:45 p.m. It was attended by E. R. Blout, D. S. Grey, R. C. Jones, C. H. Matz, M. Parrish, Jr., and H. Stockman.

In the first part of the meeting the writer presented an overall summary of the current status of the detector, during which a number of new and worth-while suggestions was made. These suggestions are stated later on in this report.

The primary purpose of the meeting was to discuss the mechanical features of the detector and to make preliminary estimates of the materials and weight of the various components. It was assumed that the radius of the spherical reflector was one foot and that the diameter of the entrance window was 9". This corresponds to a numerical aperture of 0.75, and to a circle of confusion 2° in diameter for a point target. That part of the complete sphere which will actually be required consists of a section 9" wide and 29" long. It was estimated without detailed calculation that a mirror of adequate rigidity could be constructed from aluminum with an average thickness of 3/8", or from a plastic material with an average thickness of 1". In either case the weight of a single reflector would be 10 pounds.

It was furthermore assumed that two separate reflectors would be used, one for the channel employing thermocouples and the other for the channel employing photoconductive cells. It was decided that the remaining mechanical parts required to make a complete enclosure could be made of very light weight material. It was proposed that the individual reflectors be arranged so that when both of them were used simultaneously there would be no wall between the two separate optical spaces, but that they would be arranged so that either could be used by itself with a complete enclosure. See Fig. 1.

The main drive motor required to achieve the rotation rate of 24° per second and the associated relatively heavy bearings were assumed to weigh 10 pounds.

The silver chloride window of 1/8" thickness was assumed to weigh 3 pounds.

The equipment required to chop the light falling on the photo-conductive cells was assumed to weigh 5 pounds.

The electronic equipment was assumed to weigh 10 pounds.

An assignment of 5 pounds was made for miscellaneous light weight mechanical parts, including the aluminum sheeting to enclose completely the optical systems.

The total of these separately estimated weights is 56 pounds if one considers that two reflectors and two windows are necessary. Since the various weights in many cases represented very rough estimates, it was felt that the total estimated weight was in good accord with the design objective of 50 pounds.

It was agreed that detailed mechanical drawings could not be made until more detailed information was available about the nature of the stabilized platform upon which the hemispheric search detector is to be mounted. The question was raised as to whether the basic limitation involved in the stabilized platform was a matter of weight or of moment of inertia. If it is the latter, the design should be altered in such a way as to place most of the weight near the center of rotation.

The Chopper

The chopper which serves to modulate the light falling on the photoconductive cells at the rate of approximately 800 cps was given considerable discussion. The writer's proposal to the meeting was a cylindrical hoop with a radius slightly greater than the radius of 6" along which the 18 detectors are to be located. The hoop would be approximately 1/2" wide and would consist of sections alternately open and opaque. See Fig. 2.

The requirement that the signal be synchronously rectified serves to determine the angular length of the open and closed portions of the hoop. Because the openings move in the direction of the length of the detecting strips, the phase of the modulation will not be the same at at the two ends of the strip. If one requires that the synchronous detector yield an output for a signal on the end of the strip which is not more than one db less than the signal obtained from the center of the strip, then it follows that the total phase difference between the two ends of the strip cannot be more than 60°. Since the length of a detecting strip is approximately 7°, it follows that the total angular length on the hoop of an open strip plus an opaque strip cannot be less than approximately 42°. If 45° is used, then eight openings may be placed around the circumference of the hoop. The required rate of revolution to obtain a frequency of 800 cps is then 100 revolutions per second, or 6000 rpm. It was felt that this rate of revolution was not impractical with a light and well balanced hoop.

An alternative suggestion was made by Mr. Grey. He pointed out a notable advantage which would be obtained if the circumferential length on the hoop of the open and opaque portions were each made equal to 3.5°: half the length of the detector strip, the detecting element would not respond to the temperature of a uniformly illuminated sky. This is an advantage which would be much desired with the thermopile detector, but is not of much moment with a photoconductive cell.

A further complication is involved in Mr. Grey's proposal as follows: With this proposal the phase difference between the modulation at the two ends of the strip is 360°. Accordingly, the output of a synchronous rectifier would be zero for several positions of the target on the strip. In order to meet this difficulty, Mr. Grey suggested that two separate synchronous rectifiers be used, adjusted in phase quadrature to one another. He suggested that each of these two signals could be separately displayed on the presentation screen. This would, of course, mean 36 presentation channels instead of 18 as previously proposed.

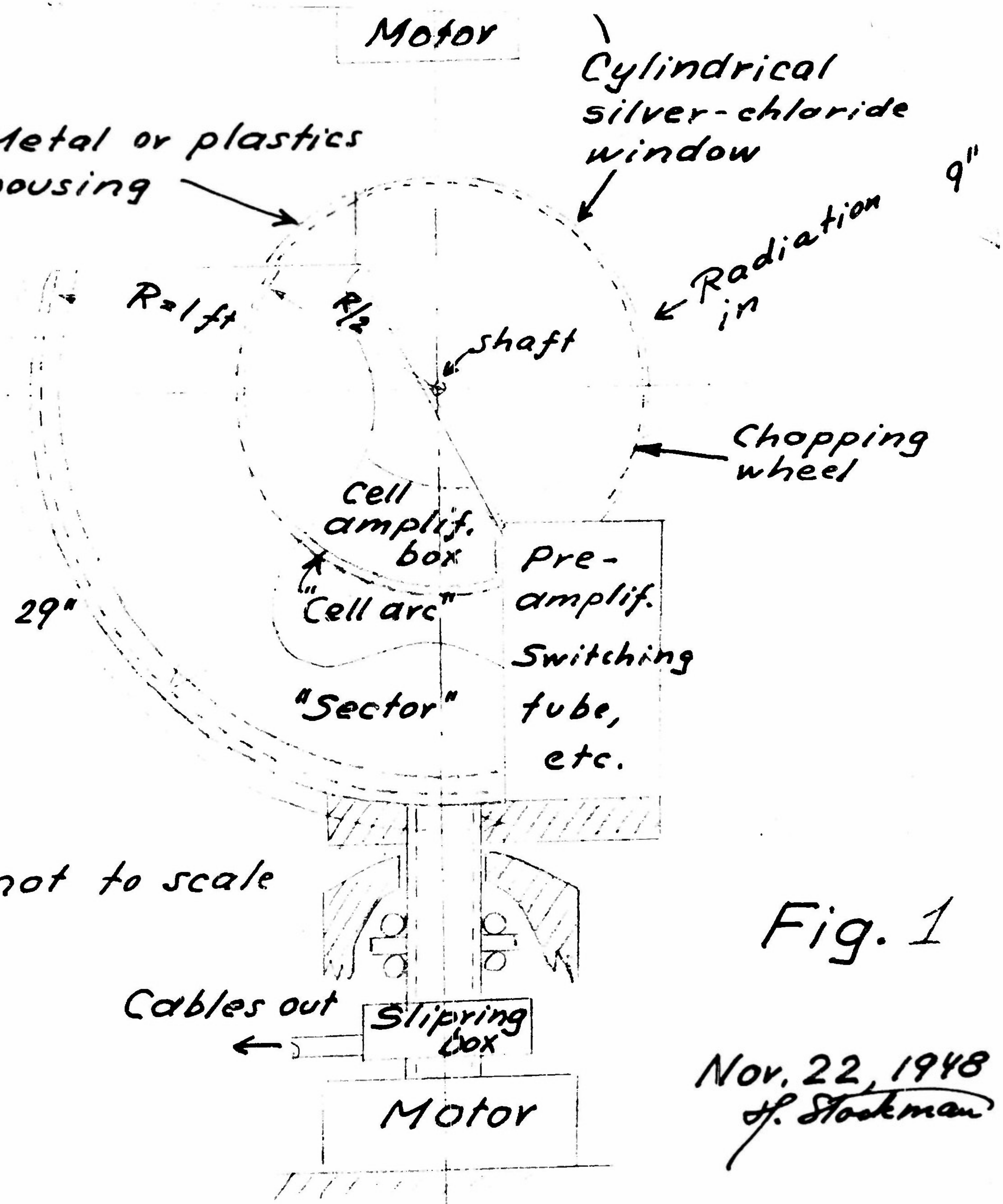
It might at first be thought that the outputs of the two synchronous rectifiers in phase quadrature to one another could be sent through separate full-wave rectifiers, and that the outputs of the two full-wave rectifiers could then be superposed. Unfortunately, this prodecure cannot be used because it leads to a reduction of 3 db in the signal-to-noise ratio. The same loss of 3 db in signal-to-noise ratio occurs if the signal from the photoconductive cell is subjected to simple rectification rather than synchronous rectification.

Dr. Matz suggested that the chopping be obtained electrically, by chopping the voltage applied across the photoconductive cell. Examination showed, however, that this procedure would modulate up to 800 cycles the low frequency noise of the photoconductive cell, so that the advantages of the chopping process in increasing substantially the signal-to-noise ratio would be lost.

The figures attached to this report were prepared by Dr. Stockman.

rcj/cbb

System

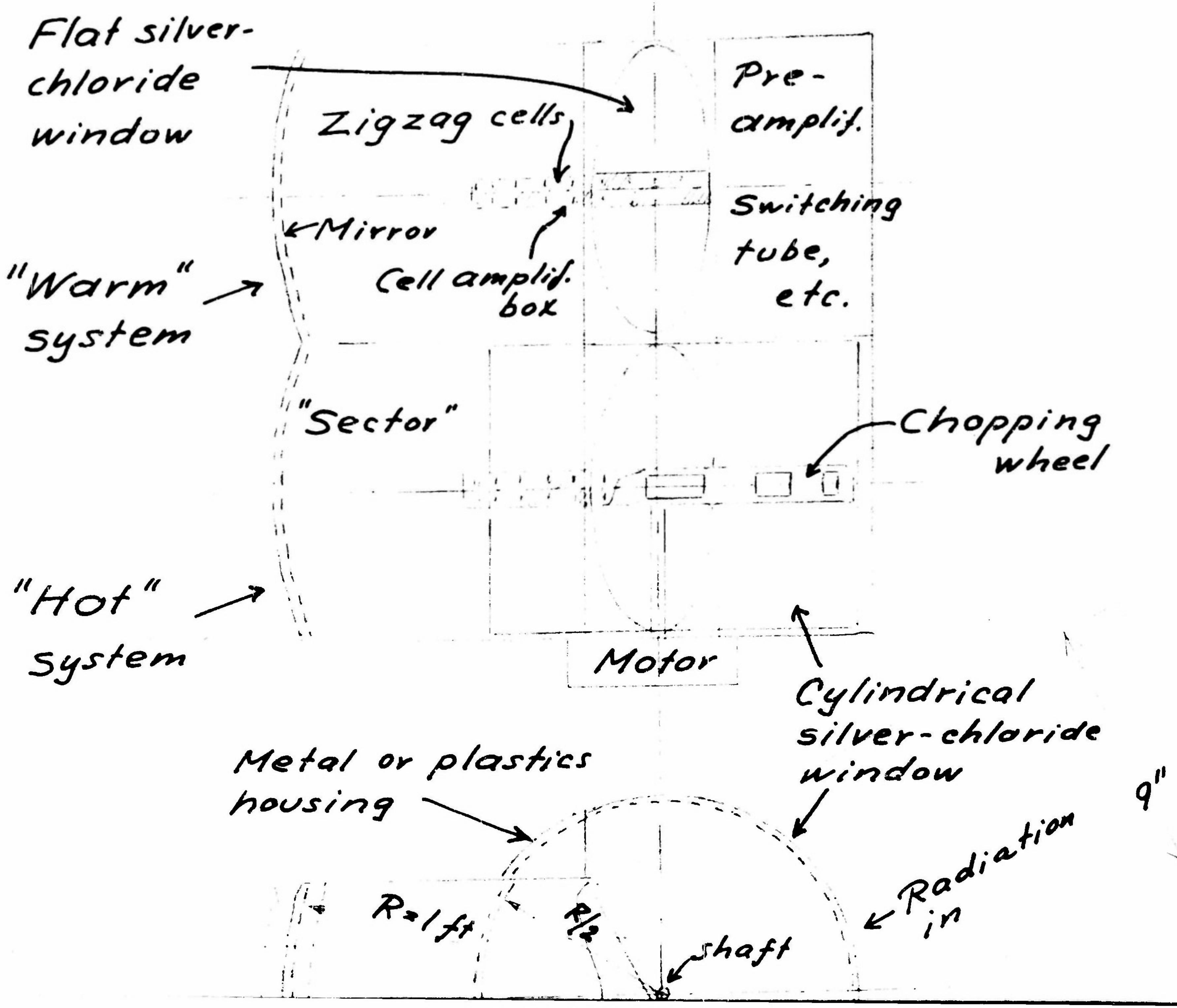


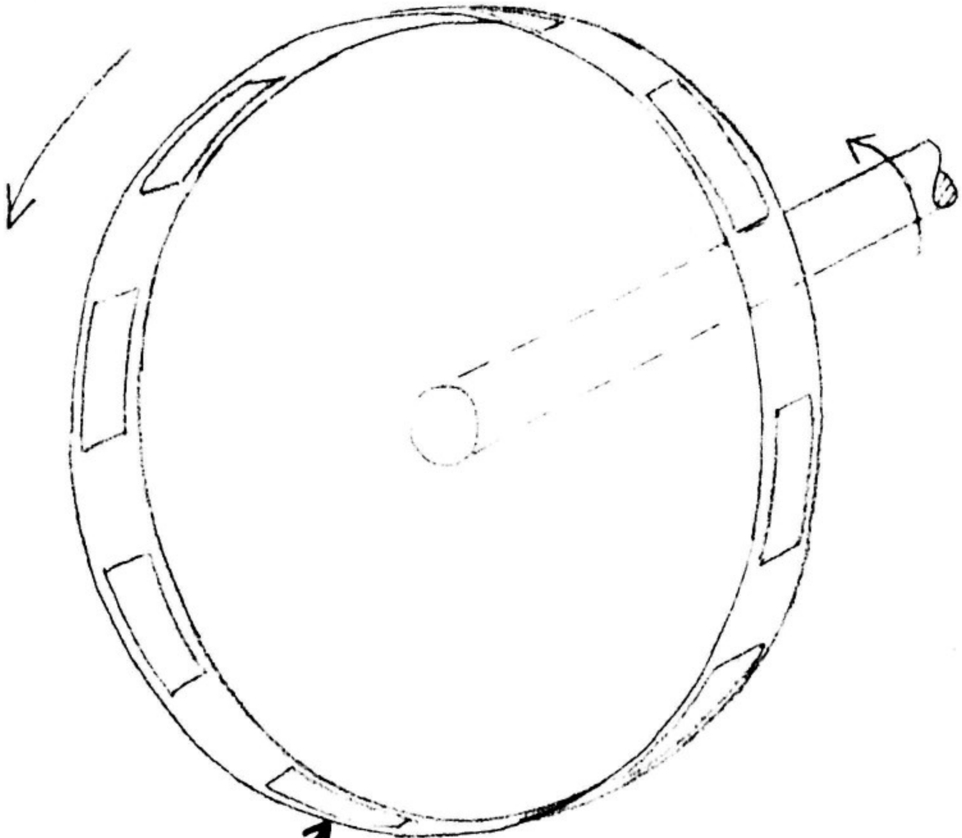
Drawing not to scale

Fig. 1

Nov. 22, 1948
H. Stockman

Mechanical Design





$360°/16$ window

Fig. 2
Nov. 17-48. H.S.

Display Unit for the Hemispheric Search Detector, Model 1

December 2, 1948

CONFIDENTIAL

Harry Stockman

The essential functions of the Monitor PPI tube in the electronic system with reference to added "memory" types of tubes may be described as follows:

a. To provide a plan position indication of the scanned area in the form of a bird's-eye view, and to indicate the position of any detected target, giving the elevation in the form of the radial distance from a point representing zenith.

b. To present all target indications by means of a slow rotating, fast sweeping "radius vector," carrying a superimposed zigzag deflection as part of the anti-zigzag circuit. (See "Anti-Zigzag Circuit for the Hemispheric Search Detector, Model 1," November 2, 1948.)

c. To use a PPI screen with a tentative time constant less than one second, associated with other PPI's with arrangement for artificial "memory" so that the past history of the target may be displayed for a time duration as large as one minute.

d. To combine instantaneous recording with memory recording in one display, all desired information being available at a glance on a display panel.

e. To indicate the position of the target sharply, maintaining given resolution figures in azimuth (normal to the radius) and in elevation (along the radius).

f. To provide the indication of the individual target with proper signal dynamic range, so that the minimum target signal strength is at the noise level, while the maximum target strength is a specified maximum illumination level; the dynamic range extending over a specified range in decibels. This range depends upon a number of factors to be discussed in later reports.

g. To record the extension of a target in solid angle of incoming radiation, represented as an area on the PPI screen. This means that a strong, close-by target (to the extent detection of this target is desirable) should not illuminate more area on the PPI tube, than what corresponds to the spread of incoming radiation over the cells in the optical scanner. The strength of the signal must not influence the coverage by more than a specified percentage figure. Thus it would be necessary to specify that for maintained input resolution, the illuminated spot must not widen out more than, say, 20 percent, when the signal level is changed, say, 50 db.

Essentially the artificial persistence circuit is needed because of the impracticability of building a single PPI tube with large time constant. It is desirable that the amount of persistence can be controlled and set to different values, and to do this in a simple way on a long persistence screen is rather difficult. The simplest solution to the problem of controlled persistence is to use several displays with fixed amounts of delay time. The original Dauber proposal, mentioned in the minutes of the October 13, 1948, meeting, provides a straight-forward approach, but the use of special multi-gun CRO's makes it desirable to provide first a type of indicator of different and simpler design, utilizing standard single-gun type CRO's. Such a system would provide PPI pictures at the times t, t + 15, t + 30, and t + 45 seconds, where t is located within a time interval 0 -- 15 seconds. A fifth CRO would be used as a monitor without any form of artificial persistence applied to the indication. A sixth CRO may be added as a "tracerscope."

Four cathode ray tubes with screens "a," "b," "c," and "d" are arranged as is shown in Fig. 1, indicating the target history at the present time $t_a = t$, and at the past times $t_b = t_a + 15$, $t_c = t_a + 30$, and $t_d = t_a + 45$. The monitoring scope "m" is arranged in the center. The system may be described in two parts, the first part considering only the PPI "a," the second one the additional equipment involving PPI's "b," "c," and "d." A third part may be added, describing the sixth CRO in the form of a display PPI "e," which combines the indications of scopes "a," "b," "c," and "d" so as to show, to the extent possible, the track of the target passing a certain part of the field of observation.

In Fig. 1 the scopes show the following displays: for an assumed time constant of the order of one second, "m" gives indication only for approximately 1/15 of the total azimuth angle of 360°; anything trailing the radius vector further back than approximately 30° vanishing. Not even noise is reproduced on the non-active 330° of the screen. Scope "a" shows the assumed single target plus background noise, but only during the last encountered 15-second interval. Information older than 15 seconds is not included in the "a"-scope presentation. Scopes "b," "c," and "d" show the same information as scope "a," only at earlier time intervals, as previously described.

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Circuits for PPI "a"

Considering an indicator in the simple form of one PPI "a" with associated artificial persistence circuit, the following points may be made:

a. A transparent pattern with 18 rings, divided into 360°, is placed over the screen, so that wherever a target indication appears, the azimuth and elevation of the target can be directly read off with an accuracy given by the total accuracy of the entire optical and electronic system. The reading is easy, as the target essentially remains in the same position and shows constant illumination intensity.

b. The incoming, operating signal is split into two parts, one which provides Z-modulation on PPI "m," and one which goes into the magnetic recorder or "drum" R-a, for storage. The indicated design of the recording unit is symbolic and only serves the purpose of conveying to the recorder designer the general information on required systems behavior.

c. The following tentative assumptions will be made for the purpose of reasoning, and concern what will be termed a "standard" target. If the output resolution is 2° in azimuth, and the B-frequency 200 cps, then there will be approximately 8.3 radial B-sweeps per degree, occupying an azimuth scanning time of approximately 0.04 second. If therefore the target would occupy a 2° display sector, it will consist of essentially 17 radial traces, which may float together on a CRO screen into one illuminated spot. If the time constant of a screen is of the order of one second, the front edge of the target response will show full light intensity when the back edge is still in the process of being completed. The spot so produced will then stay on, rather evenly illuminated, for about a second before the light intensity is down to a third of its value, i.e., during the time the radial sweep describes an angle of 24°.

d. Figure 2 shows in an elementary way the arrangement with the recording head symbolized by two thin magnetic edges n, s, so that if the tape moves with the velocity v, and a pulse is applied during the time t to the windings N, a "bar" magnet of length vt results. A complete sweep of duration $T_A = 15$ seconds corresponds to a "bar" in form of a circular ring of length vT_A, and this quantity is of the order of one foot.

e. Figure 3 illustrates one possible arrangement for simultaneous repetition of the interval T_A on 18 tapes or rings, arranged to provide a "drum" surface, making one complete revolution in 15 seconds. (Alternatively the drum may be fixed and all heads rotating.)

f. Figure 3 indicates that when the pickup head is passing the recording head, a spurious signal may be injected which is not a true signal "bar," recorded into the magnetic surface. To prevent this a blanking signal may be arranged to blot out the direct signal from the recording head. For accomplishing this the recording head may carry a high-frequency signal above the cut-off frequency of the wire magnetic material, which signal is picked up by the pickup head and used to excite, after proper rectification, the blanking circuit. Another possibility is to make one head jump out of the way for the other, when passing.

g. The various frequencies involved will now be reviewed with reference to Figs. 1, 2, and 3. The monitoring scope deflections f_A

and f_B follow the deflections of the line switching tube. The circular sweep on all other CRO's is faster by the factor k, which may be tentatively set to 10 to 50. The radial deflection frequency is the same for all "memory" CRO's, and has a higher value than that used for the "m"-scope. The sequence of input signals is applied to a switching tube, the plate electrodes of which are directly connected to the fixed 18 recording heads. The resulting, saw-tooth, B-sweep, is symbolically shown on the ring surface of the recording unit R-a. The synchronization is such that the i:th ring is always connected to the incoming line just when the i:th pulse arrives from the i:th cell in the optical scanner. After a complete 15-second revolution of the "drum", all targets received by the optical scanner are properly engraved at the right places on the surface of the drum. Due to the higher speed of rotation of the axially arranged, inside pick-up heads, the pick-up scanning frequency is sufficiently high to illuminate the targets on the "memory" of CRO "a" at a rate above the flicker rate, and the CRO "a" appears to have an infinitely long time constant, i.e., infinitely high persistence.

h. The connection between the fast rotating pick-up heads and the CRO "a" is as follows: As is symbolically shown in Fig. 1, the recording unit R-a is indirectly connected to the cathode modulation contact of CRO "a." The problem is now to connect consecutively each one of the 18 pick-up heads with the CRO "a," so that the i:th head is always the one connected when the CRO beam is deflected radially to the i:th channel. Two synchronization circuits are involved: the one that makes the circular sweep of CRO "a" follow the circular movement of the pick-up heads relative to the drum (utilizing the synch-marker shown), and the one that makes the radial deflection of CRO "a" synchronize with the axial saw-tooth sweep from head to head, accomplished by a storage switching tube. This tube is conveniently built with 19 electrodes, of which one serves as a synchronization electrode. Tentatively, the radial deflection frequency in CRO "a" may be assumed to be of the order of 10,000 cps. (At this first approach to the problem the undesirable ratios between certain parameters are rather discouraging.)

Extension of CRO's "b," "c," and "d"

The complete arrangement with four high persistence CRO's involves the use of four recording units R-a, R-b, R-c, and R-d. Each one has 18 tracks for recording of the various cell outputs through a complete 15-second revolution. The following points are of particular interest.

a. Considering the basic principle, and starting at the time t = 0, the recording unit R-a is connected to CRO "a," so that after 15 seconds all targets are permanently recorded on the R-a "drum," and by means of the scanning pick-up heads repeatedly reproduced on the "a" screen. At this instant recording unit R-a is switched over to CRO "b," and the past history of CRO "a" is now repeated on the screen of CRO "b." At this instant, simultaneously with R-a being connected to CRO "b," a new and unused recording unit is connected to CRO "a," and during this second 15-second interval, it is convenient to rename unit R-a to R-b, and to call the partly unused unit R-a. During the third 15-second interval, unit R-b becomes R-c, unit R-a becomes R-b, and a new unit is thrown in as R-a. The procedure is repeated during the fourth 15-second interval, during which R-c becomes R-d. During the fifth 15-second interval, unit R-d becomes R-a, but all magnetic recording is erased before the magnetic material can be acted upon by new incoming signals. In this way all the recording units pass through the same one-minute cycle, and the desired result is achieved by having CRO's "b," "c," and "d" show screen patterns, all respectively delayed 15 seconds.

b. The recording unit switching action is very slow, and can be accomplished either with contact springs or with still additional switching tubes.

The Tracerscope "e"

The CRO showing the continuous signal track of a target, to the extent this can be accomplished, is in principle a linear mixer tube, receiving simultaneously all the signals that normally go to tubes "a," "b," "c," and "d." It is believed that this will result in approximately twice as much background noise on the screen. The result may be the one pictured in Fig. 1 (the trace a - d).

A New Suggestion

During the meeting in Washington, November 22, 1948, Mr. Dauber suggested the simplification of using only two CRO's, one to carry out the function of the monitoring scope "m," the other to carry out any chosen function of scopes "a," "b," "c," or "d." The circuit arrangement should be such that any one display can be superimposed on any other display, and ultimately all four displays "a," "b," "c," and "d" superimposed to yield the tracer-scope display "e."

HS/h

Display unit

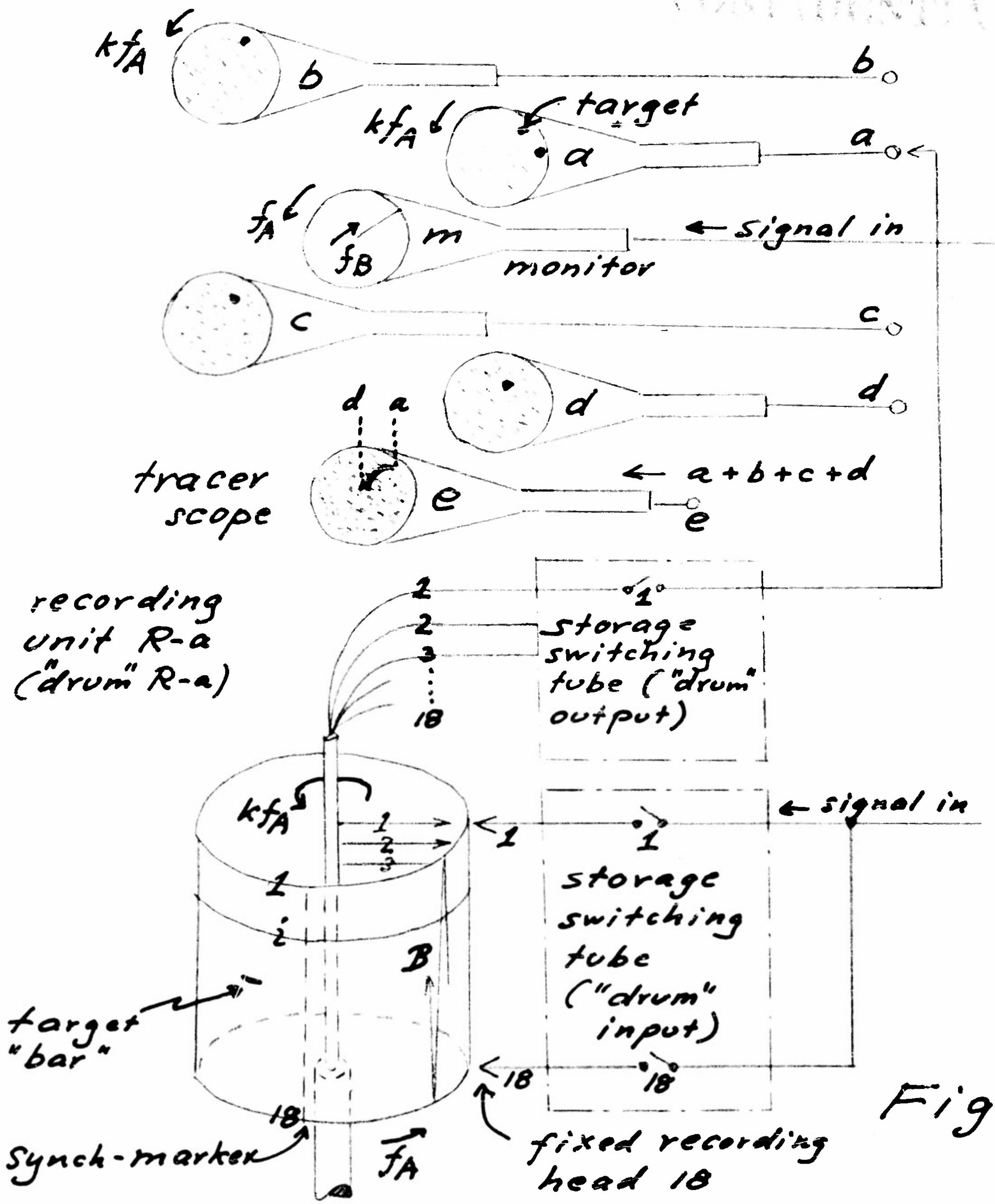


Fig. 1

Nov. 1-48
[signature]

Display unit

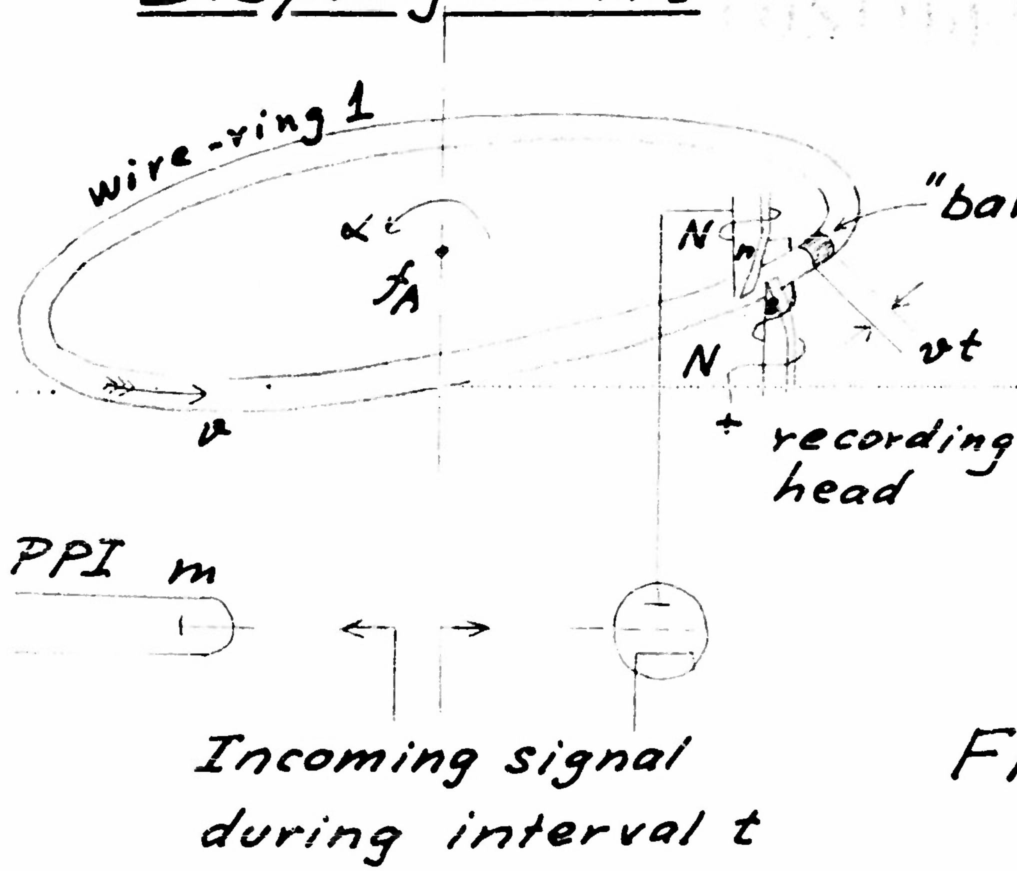


Fig. 2

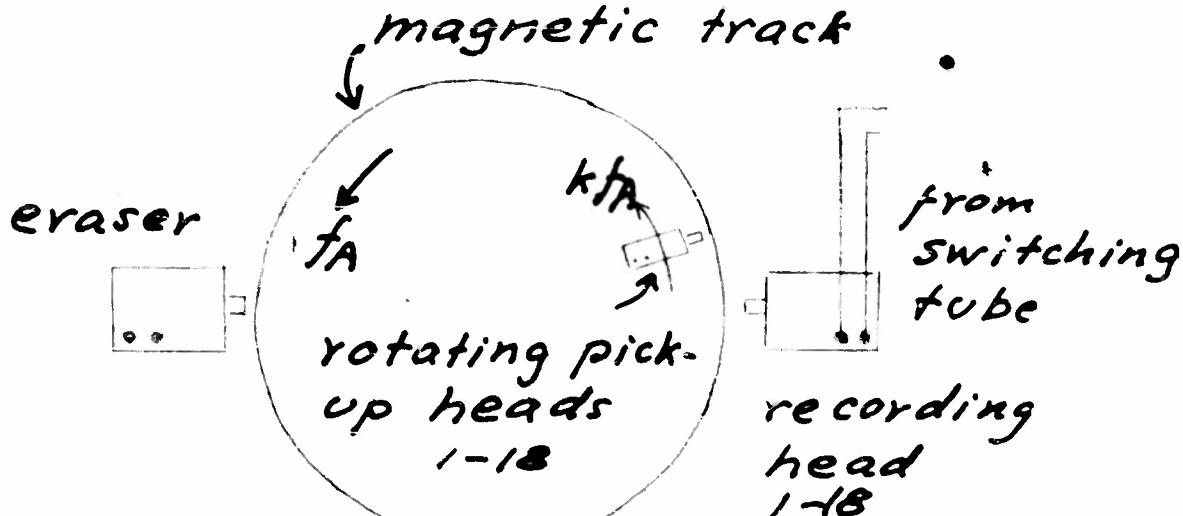


Fig. 3

Nov. 1, 1948

H. Stockman

Mechanical Design of the Hemispheric Search Detector, Model 1

November 22, 1948

Harry Stockman

For a proper discussion of this subject the latest form of the overall electronic system for the search detector (dated November 22, 1948) will first be considered, see Fig. 1. For proper tube operation all amplification on top of the mast has been placed prior to the switching tube. Added amplification for low noise transmission through the cable has not been deemed necessary. It is estimated that an amplification of roughly 120 db is required prior to the switching tube with the amplification properly divided between the cell-amplifiers and the channel amplifier. Automatic gain control, AGC, circuits are provided individually for each amplifier, as in this way fast operation can be secured. Additional AGC circuits may be required, as is symbolically indicated in the diagram, Fig. 1. It may be found desirable also to apply AGC action to the individual radiation detectors, although this has not been suggested in Fig. 1.

The cell-amplifiers may be mounted directly behind the cells in a box, including the "arc of cells," and additional housing arranged just outside the "sectors" for subsequent amplification. All this electronic apparatus rotates with the optical scanner.

Two optical scanners are used with completely duplicated electronic equipment, the "warm" thermopile scanner, and the "hot" lead sulfide scanner. The latter requires an optical chopper, and a method for arranging this chopper, shown in Fig. 3, has been suggested by Jones and Parrish, and will be discussed in the following. Both optical scanners, with associated equipment, are mounted on a stabilized platform with slip ring arrangements for input power and output signals. Instead of a dome surrounding the entire rotating device, silver chloride windows are used in both "sectors," covering the entrance pupils, and in the case of the "hot" channel also the chopping wheel. For the time being the problem of cooling or no cooling will be left out of consideration.

Figure 2 shows the proposed design. All suggestions implied are tentative, as changes in the components will affect the final design considerably. The two "sectors" containing the spherical mirrors, or reflectors, are mounted in fixed positions side-to-side on the rotating platform, supported by the vertical shaft. Each "sector" contains a cell-amplifier box, housing the cells, cell-amplifiers, and associated circuit components. Boxes for preamplifiers, switching tubes, and associated equipment are mounted on each "sector" and properly connected to the cell-amplifiers.

The two "sectors" differ in some respects, as different kinds of cells are used. The essential difference is the chopping wheel, Fig. 3, mounted in the "hot" system sector. This wheel has eight apertures in cylindrical arrangement along the rim, which means that the rotational speed of the wheel is considerably reduced from the speed required for a single aperture arrangement. The shaft of the chopping wheel is held in position by a bearing, associated with the outer wall of the sector, and with the foundation for the driving motor. The nearness of this motor to the sensitive electronic circuits puts high requirements on the shielding and decoupling arrangements. It is also possible that the fast rotating chopping wheel may cause disturbances due to electrical charges in the wheel and associated equipment.

The silver chloride window for the "hot" system is combined with the housing for the chopping wheel, as is indicated in Fig. 2. The shape of the silver chloride dome is such as to let through all active radiation, and adjacent parts of the housing are made of more suitable material, metal or plastics, not transparent to the incoming radiation.

For a minimum chopping frequency of 500 cps, the required speed of the wheel is 3750 rpm. For 800 cps the speed becomes 6000 rpm, and for this higher speed various difficulties in mechanical design may be encountered.

The following tentative figures for the weight of the major components have been arrived at:

	Pounds
Two "sectors" of cast aluminum of 1 foot radius, 3/8 inch thick, including 9" x 29" spherical mirrors (reflectors), 10 lbs. each	20
One silver chloride window, 1 - 12 μ transmission, for the "warm" system	2
One silver chloride window, 1 - 12 μ transmission, for the "hot" system	4
Rotating scanning system (chopping wheel, plus shaft, plus bearing, plus motor)	5
"Arc of cells" with cell-amplifiers, etc., in position, 1.5 lbs. each	3
Preamplifiers with housing, 1.5 lbs. each	3

	Pounds
Switching tubes and associated equipment and housing, 2 lbs. each	4
Main shaft, bearing, slip ring box, motor, etc.	10
Miscellaneous	5
	56

hs:cl

'lectronic System, Nov. 22, 1948.

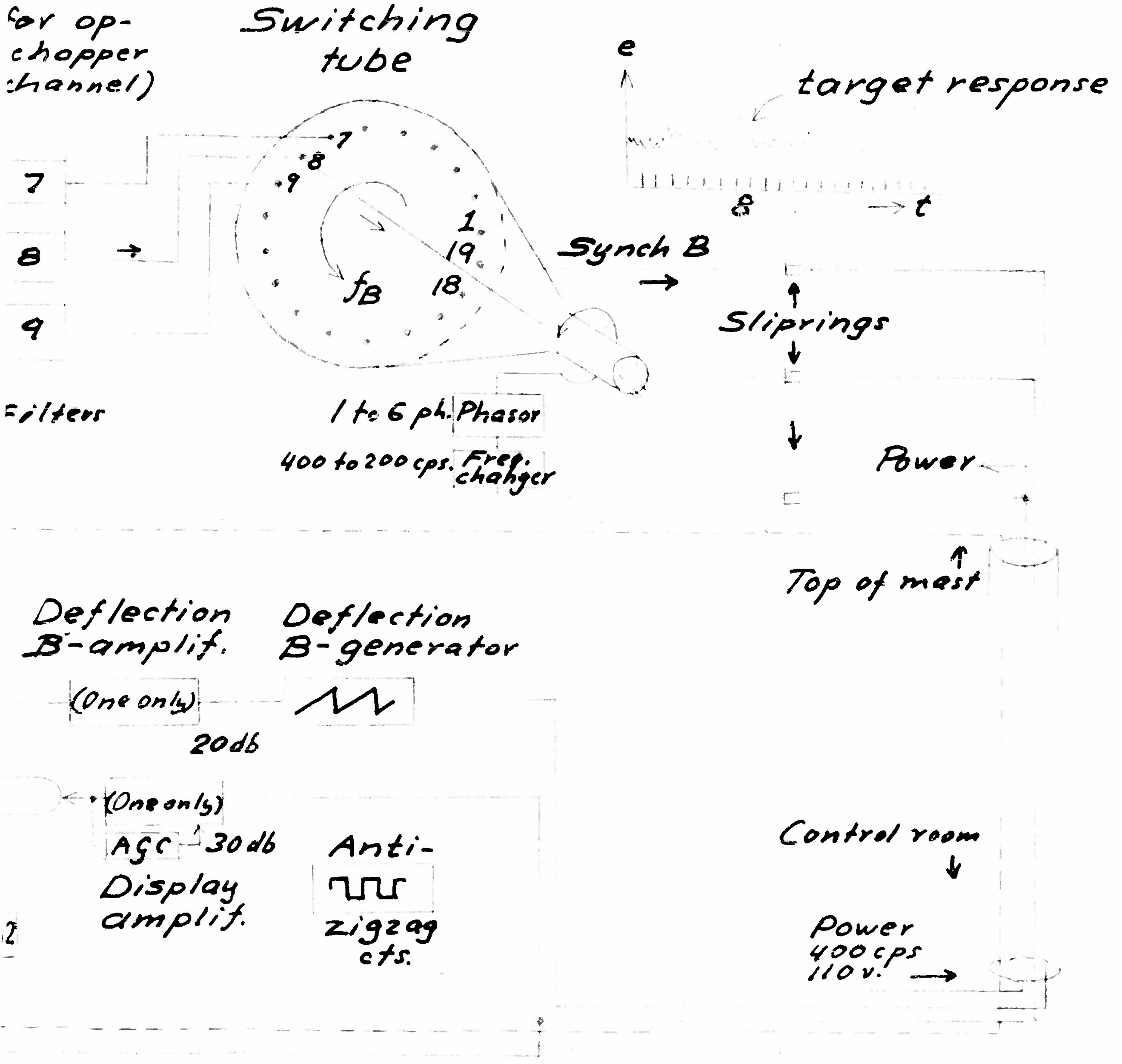
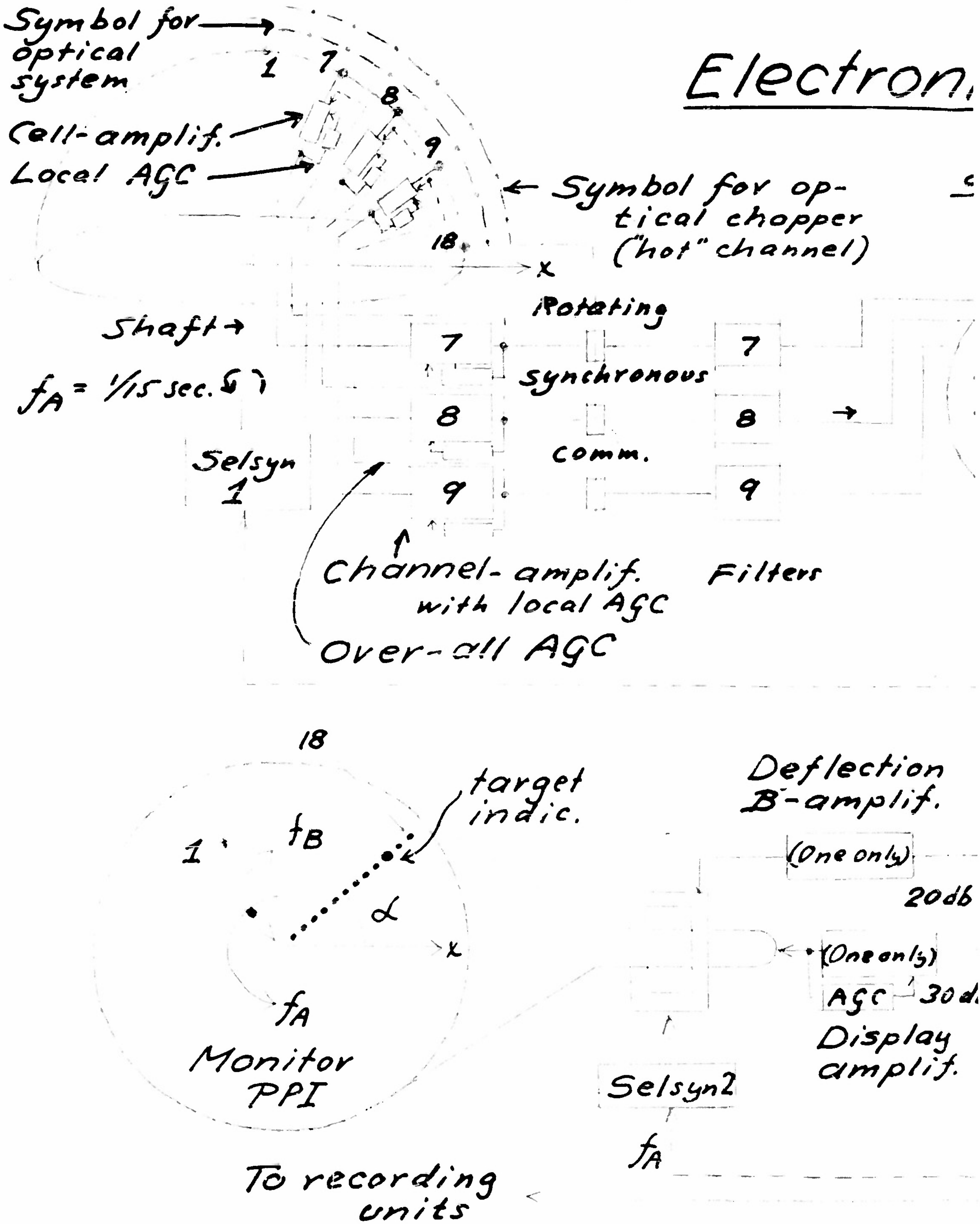


Fig. 1

Nov. 22. 1948
H. Stockman

Electron


Symbol for optical system
1
7
8
9
18
Cell-amplif.
Local AGC
Symbol for optical chopper ("hot" channel)
x
Rotating synchronous comm.
Shaft
f_A = 1/15 sec.
Selsyn 1
7
8
9
Channel-amplif. with local AGC
Filters
Over-all AGC
18
1
f_B
target indic.
α
x
f_A
Monitor PPI
Deflection B-amplif.
(One only)
20db
(One only)
AGC
30d
Display amplif.
Selsyn2
f_A
To recording units

F

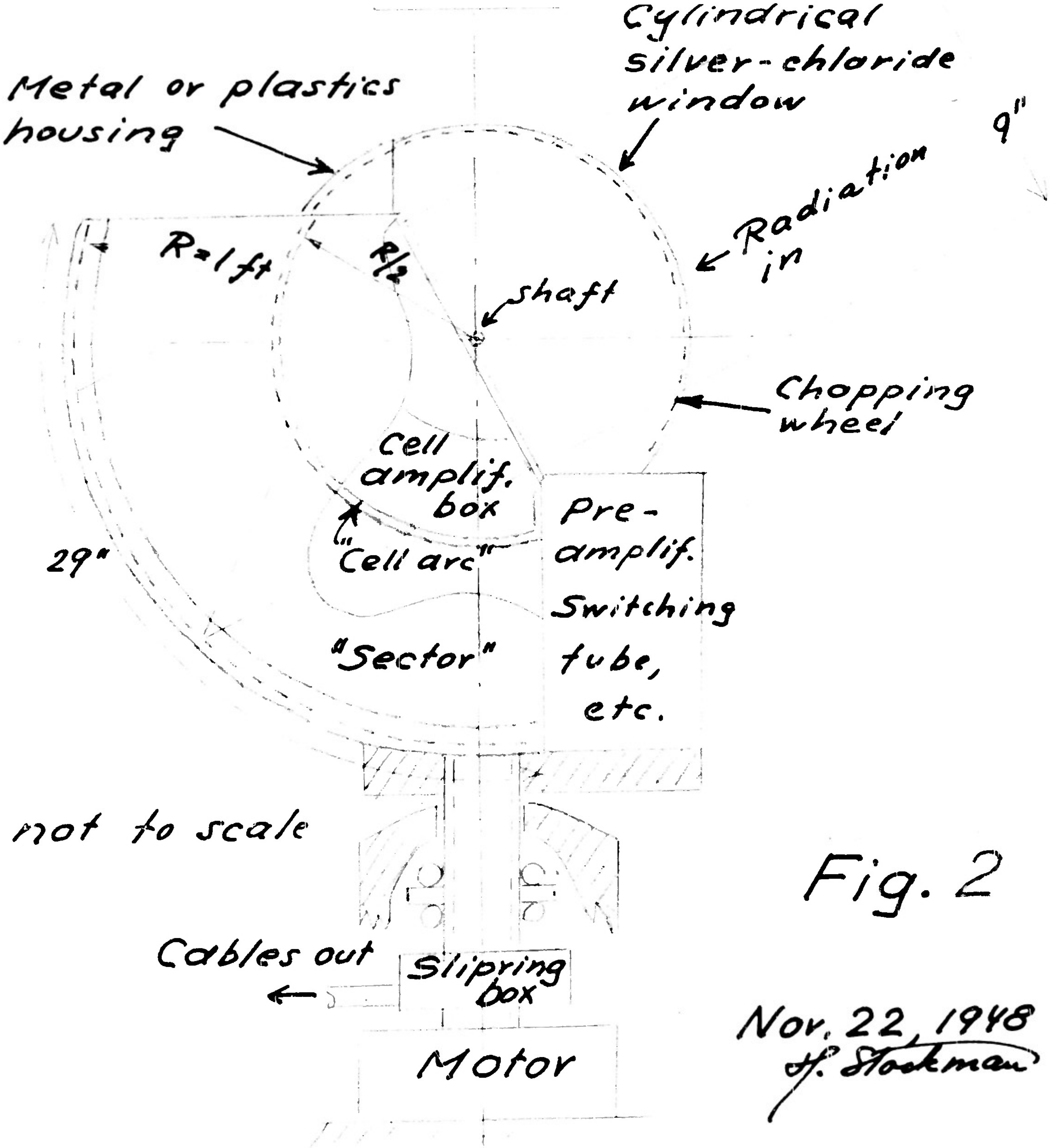


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Fig. 2

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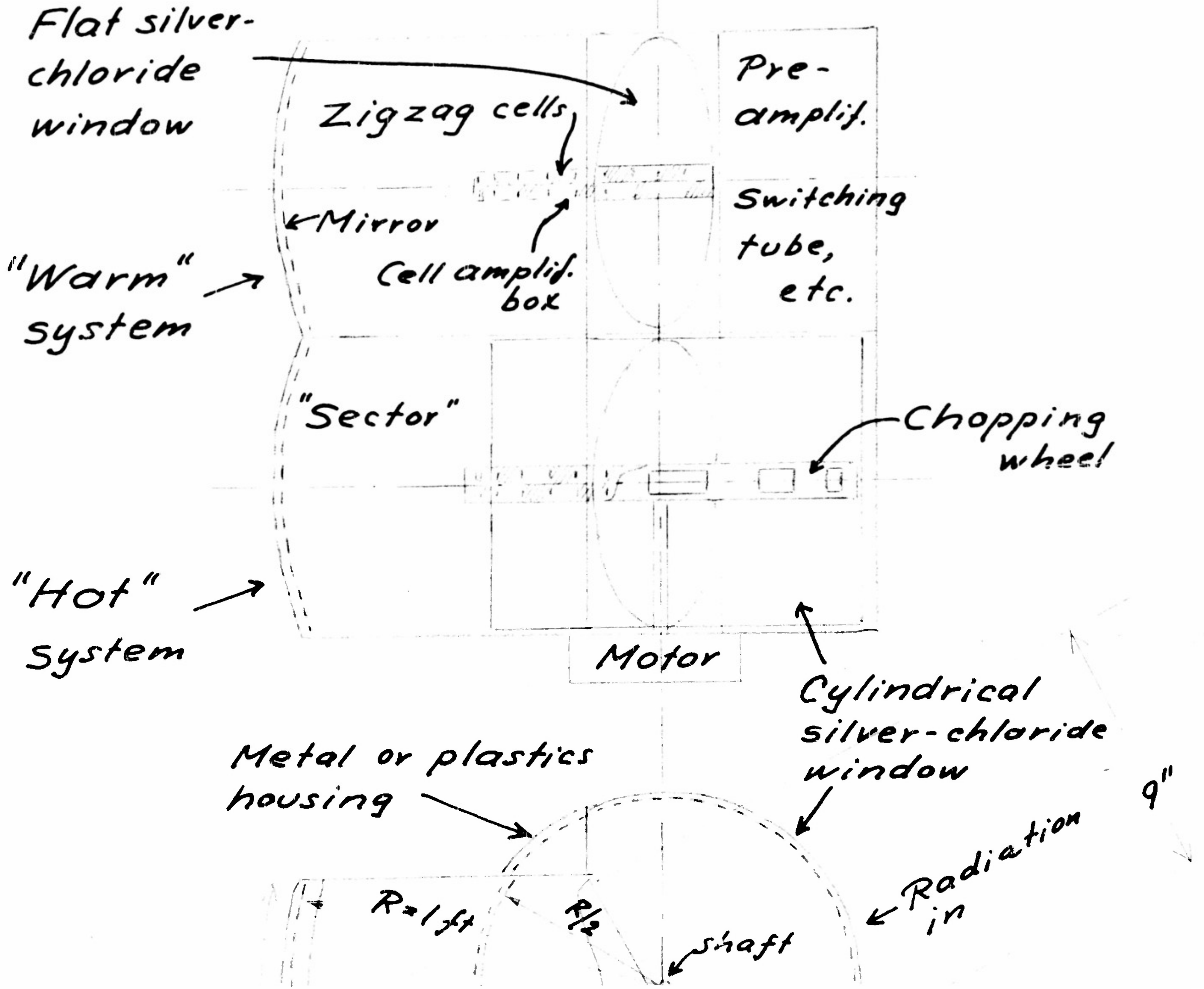
Mechanical Design



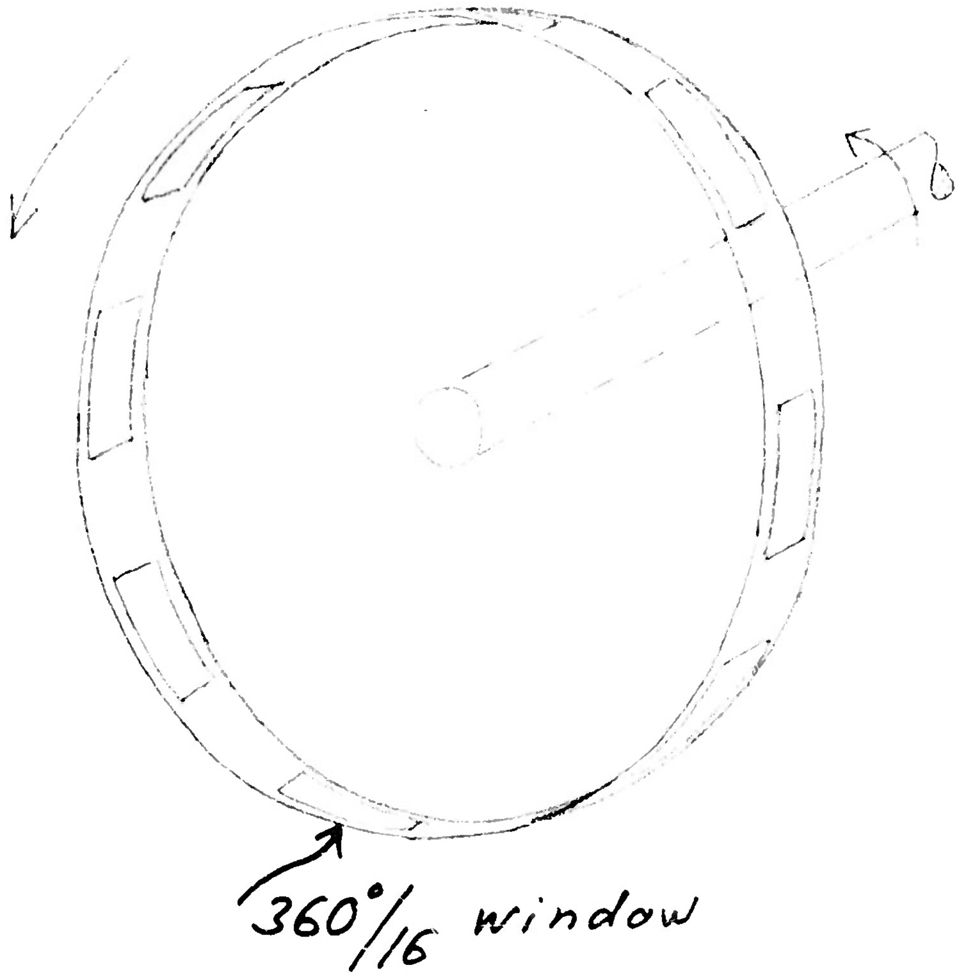


Fig. 3
Nov. 17-48. H.S.

Enclosure 6 CONFIDENTIAL

Anti-Zigzag Circuit for the Hemispheric Search Detector, Model 1

November 2, 1948

Revised December 3, 1948

Harry Stockman

It is desirable that the search detector show a continuous response as the elevation angle is varied, so that no targets are lost due to "vertical" discontinuity between cells in the optical scanner. For this reason the cells in the scanner are staggered or displaced a specified distance in the direction of the scanning, approximately equal to the width of the individual cells. It is desirable that the indicator operate in such a way as to undo the effect of staggering, so that the appearance of the CRO presentation becomes that of an ideal scanner with straight-line arrangements of the cells, free from discontinuities.

If a point target is received on the borderline between two cells, or if the target has the form of a vertical line radiation, some of the response will come in on the first encountered cell during a scanning azimuth angle of 2^o, or a scanning time of approximately 0.1 second, while the reminding response comes in during the following scanning angle of 2^o, and the following time interval of approximately 0.1 second. One solution is then to arrange the indicator circuits in such a way that the first response is delayed t_z seconds, where t_z is the zigzag delay time (approximately 0.1 second), and then flashed on the CRO screen at the same time as the second response occurs. Thus the effect on the indicator is the same as if all cells were mounted in a line. This is illustrated by Fig. 1, showing the scanning detector and the display CRO screen.

The desired time delay t_z can be provided in several different ways. The problem is simplified by the fact that the delay applies to one specified set of cells, for example, all the odd cells 1, 3, 5,...17. The following requirements on the delay scheme are important:

a. The delay should be t_z seconds, with an adjustment kt_z, controlled, for example, by synchronization to the frequency source f_A = 15 cps, so that the delay always is maintained at proper value.

b. The delay circuits shall perform the delay t_z without changing the character of the signal to any extent in any respect.

A delay circuit may be useful even if requirement (b) is not rigorously fulfilled, particularly if this means simplifications in circuitry.

Figure 2 shows the principle for a delay system, when the delay is introduced prior to the line switching tube. This has the advantage that from the switching tube on, the circuit is the same as if all cells were positioned in one line. It is here assumed that the responses from cells 1, 3, 5 ..... arrive t_z seconds before the responses from cells 2, 4, 6....., so that the former are the ones to be delayed t_z seconds. Each channel requires a separate delay unit, but all delay units are of identical construction.

Figure 3 shows the principle for use of independent "even" and "odd" line switching tubes. Here an "odd" output is delayed, so that the down-lead output to the indicator provides a response of the same kind as would be obtained, were all cells mounted in line. The two line-switching tubes must be properly synchronized, so that the beam in one scans an input terminal at the same time as the beam in the other traverses the distance between two input terminals. This scheme is merely included for completeness of presentation, and is not expected to be of the same practical value as the one described with reference to Fig. 2. Both these methods would require rather elaborate delay lines or storage devices, such as magnetic recorders, and it is suggested that Model 1 be built in accordance with the third method, described in the following.

The third method is shown in Fig. 4. A vertical line target is assumed, as shown in Fig. 1. Without any anti-zigzag circuit the presentation on the CRO will be the one referred to as "original presentation" in Fig. 4, only that response 11 will appear earlier and die out earlier than response 10. If now a square-wave is superimposed on the radial sweep, this radial sweep will appear to the eye as the zigzag line, shown in Fig. 4, assuming no incoming signal. When the signals from the vertical line target are applied, the resulting effect with respect to target response is the one shown to the right in Fig. 4. As before, response 11 will appear a short time earlier than the response 10, and similarly die out earlier. For proper operation the superimposed zigzag sweep should be synchronized with the radial sweep.

Other alternatives exist, no doubt, and the presented material merely serves as an introduction to this particular problem.

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$10\frac{1}{2}$

Anti-zigzag circuit

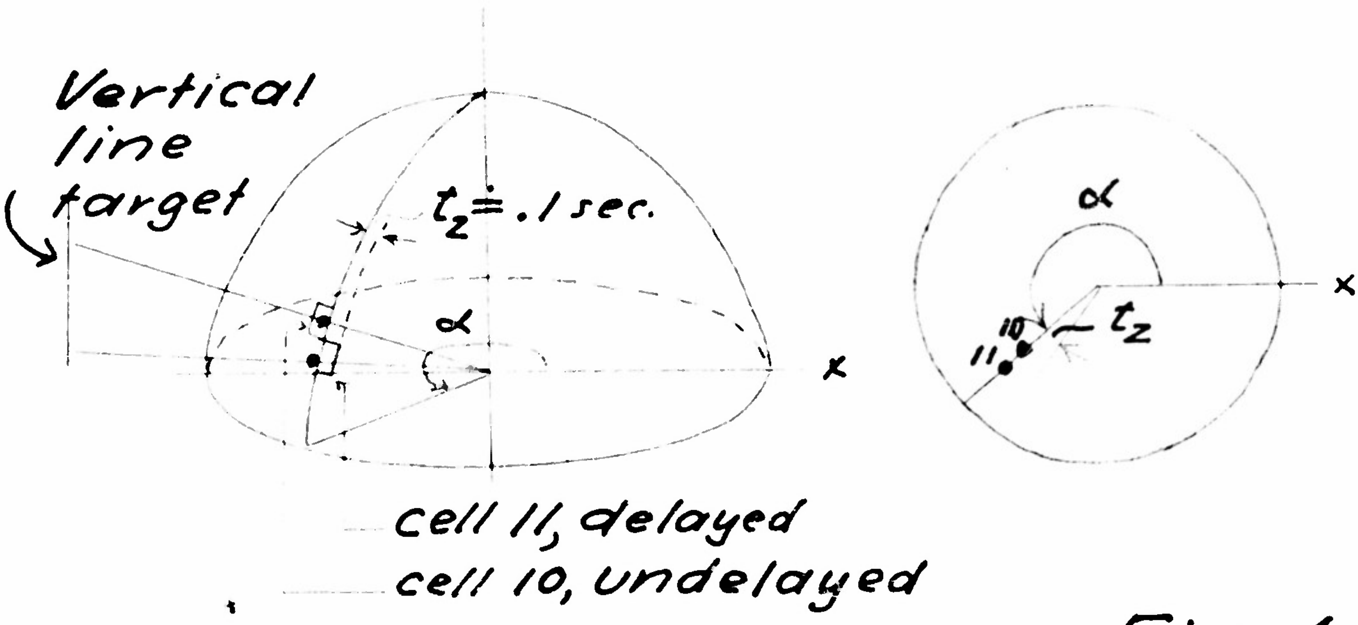

Fig. 1

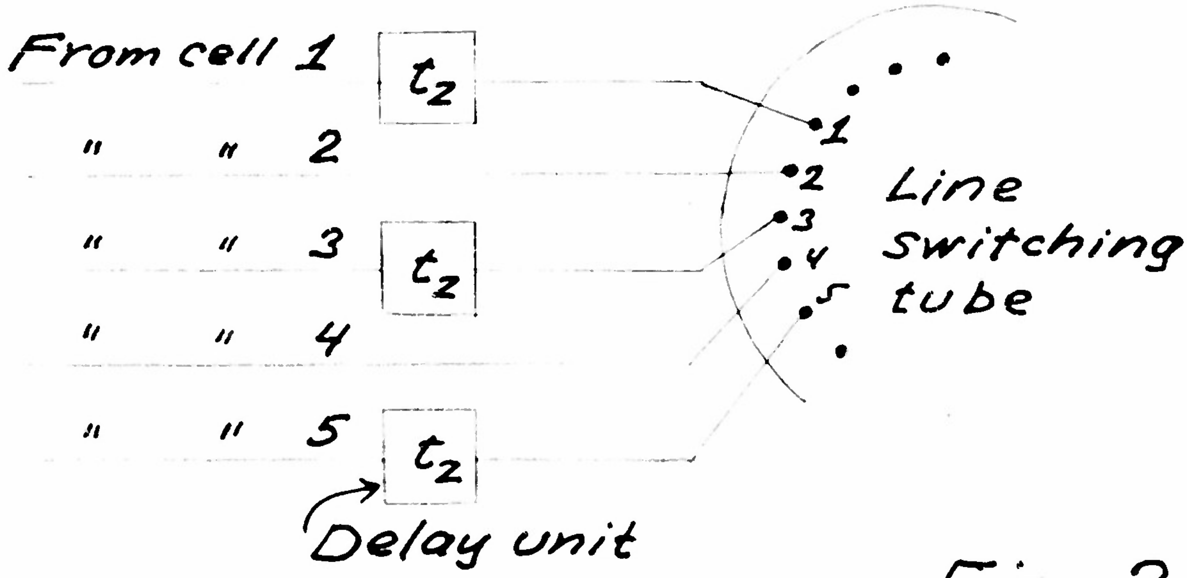

Fig. 2

Nov. 2. 1948

S. Stockman

Anti-zigzag circuit

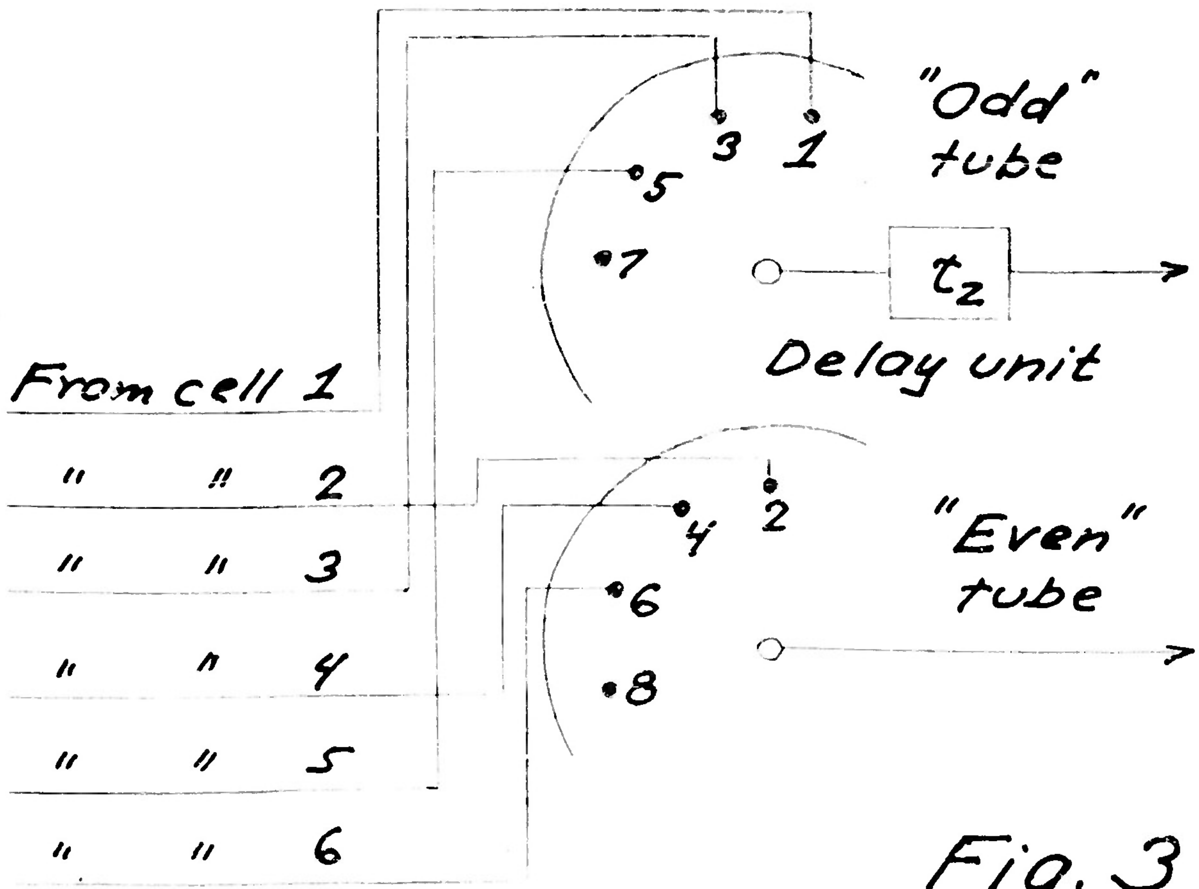

Fig. 3

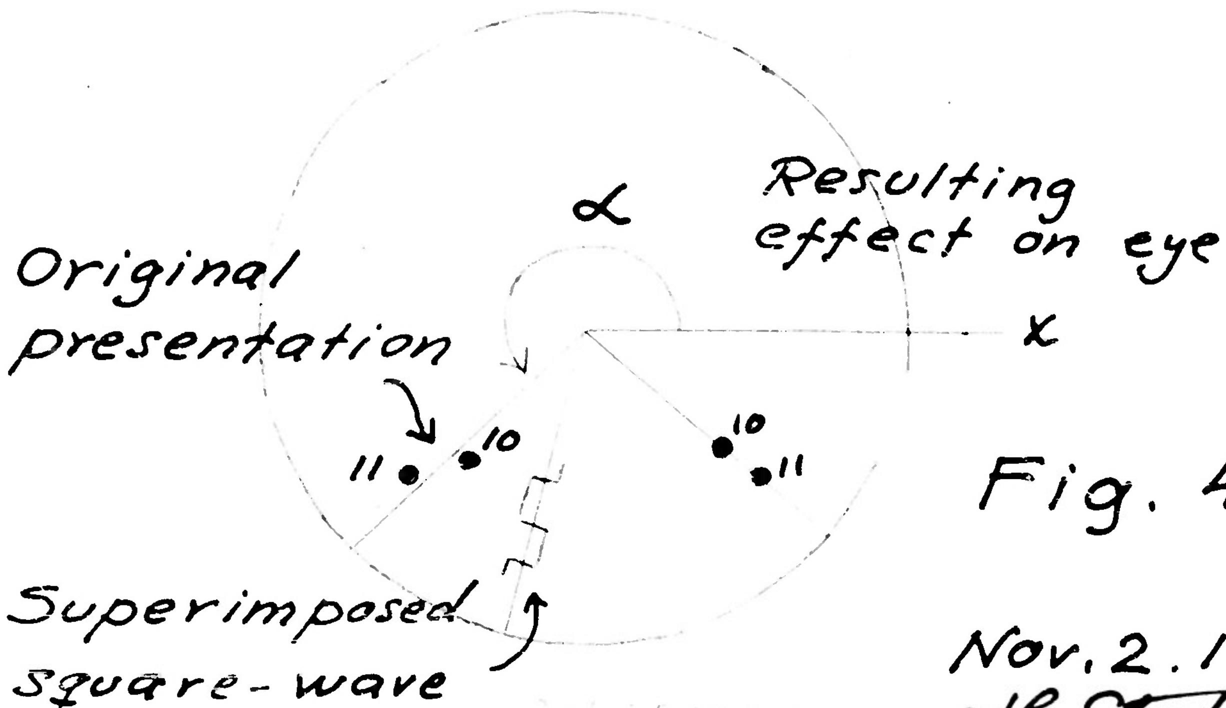

Fig. 4

Nov. 2. 1948

H. Stockman

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